THE IMPACT OF CLIMATE CHANGE ON THE WATER RESOURCES OF NORTHERN CHINA

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INTRODUCTION

Problems of water resources are becoming important factors restricting social and economic development of our country. In northern China, confliction of water supply and demand is even more intense, for instance, the water resources per capita and per hectare are only 422 m^3 and 3735 m^3 respectively, which are far below the average value of the country. Water resources of northern areas are so dramatically sensitive to climate change that a small alternation in the precipitation might bring about severe water shortage.

In the recent 50 years, it is obviously warmer in northern China than before. The particularly obvious warming in winter had not only resulted in a greater evaporation and reduction of runoff volume, but also intensified the conflicting of water supply and demand, especially in down reaches of rivers.

According to associated study, being affected by natural climate change and human activities, temperature of northern China will be going up in the coming 30 to 50 years. The indications show that a new arid period of centenary scale is likely to come. Added that the water demand is increasing steadily, the frequency and intensity of drought maybe strengthened, and most severe drought is likely to occur. This will seriously affect the sustainable development of the social economic and the livings of our human beings.

CLIMATE CHANGE AND ITS IMPACT ON WATER RESOURCES

The Huaihe River and Qinling Mountain is a natural demarcation in the north of which belongs to the semi-humid and semi-arid climate. The precipitation in this area is rather small and water resources are in shortage. The urgent situations of water supply and demand is most outstanding through out all the country.

Present Situation of Water Supply and Demand

Influenced by the geographic position and topographic situation, there is great difference between North China and Northwest China in climate and water condition, which results in the accordingly different water demand and supply.

North China lies in the half-moist and half-arid climate region and evaporation there usually outweighs precipitation. The gross water resources and water per capita and per hectare are all scarce. The population there accounts for 15 percent of the whole country, and farming lands about 17 percent, while the gross water is only 2.4 percent of the country. The water resources, the population and the farming land matched exceptionally poorly, the tension of water supply and demand is conspicuous.

As a result of the above reason, the water resources is excessively exploited and utilized. Utilization ratio of the surface water and ground water are up to 66 percent and 90 percent respectively and in some region the volume of utilization is far beyond the supplement given by precipitation.

Northwest China lies in the far-reaching arid inland and having a much less precipitation and relatively higher evaporation potent than North China, it is an area considerably lack of water. However, precipitation in mountains around this area is

fairly abundant, making the mountain areas an “moist island” and a major source of surface runoff and water resources. Compensated by the plenty of glacier, accumulated snow and ground water, the water resources of Northwest China is not very deficient compared to other arid areas of the world.

In Northwest China, precipitation provides basic water resources, not only determining the water condition, but also influencing the development of High Mountain glacier and the formation, distribution and change of runoff.

As the social economy is developing, the average utilization ratio of surface water in the whole area of Northwest China is 50 percent, whereas spatial difference is rather evident. For instance, in Xinjiang Automatic Region, the utilization ratio of surface water is 65 percent, in contrast, in Shaanxi Province the surface water utilization ratio is only 9 percent while ground water utilization ratio is 71 percent. In the whole Northwest region, the gross water consumption only accounts for 18 percent of the total water resources, which indicates that the utilization ratio is considerably low. However, in order to guarantee the sustansible using of local water resources and protect the fragile ecological environment, some urgent problems should be dealt with immediately in water exploitation and utilization, such as water wasting, water quality pollution and climate aggravation that is evoked by unreasonable human activities.

The condition of water demand and supply is a result of human activities and the climate change in the past few decades.

Temperature Change

IPCC is the authority around the world in accessing climate change and its impacts. According to the scientific report of IPCC in 1995 accessing global climate change in the past years, from 1960s’ to now, the average global temperature had risen by 0.3~0.6_ (see figure 1). As the whole globe is becoming warmer, temperature of China in the recent 50 years also rose up, characterized by evident locality and season. Temperature rose most remarkably in northern areas and in winter, figure 2 shows the temperature change curve of the recent 50 years of North China. From this figure we can see that the temperature rose gradually from 1950s’ to 1990s’, and in 90s’ the temperature rose most obviously, the mean temperature of 90s’ is 1.2_ and in winter 2.1_ higher than that of the 50s’.

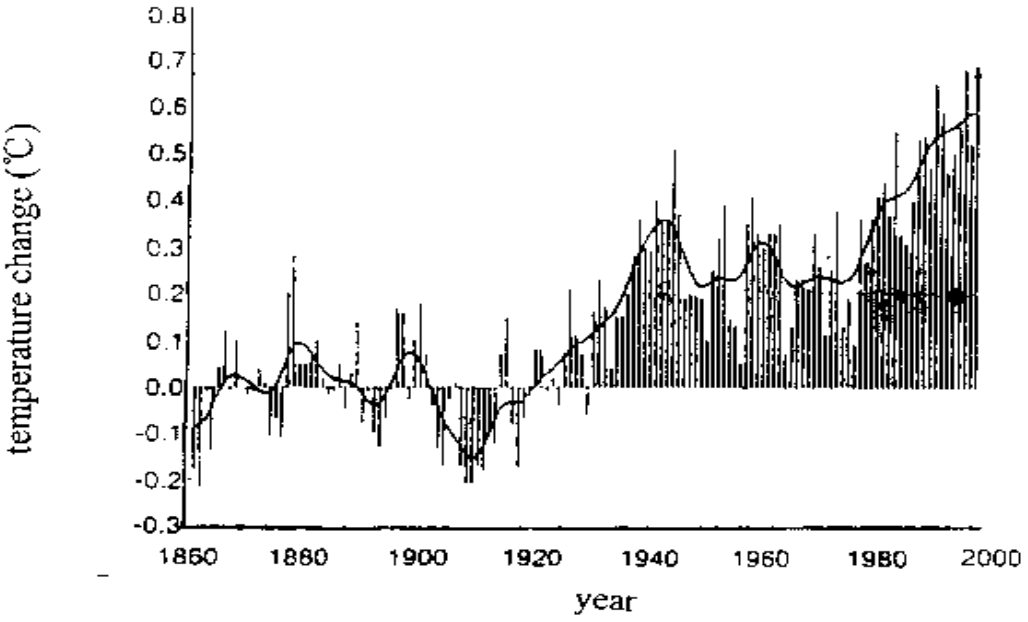


Figure 1. The global annual mean temperature changing trend according to the surface observations on seas and continents
(temperature change of 1997 includes the observation value at the end of September)

The temperature change of Northwest China differs from that of North China (see figure 3). During the recent 50years, in the 60s'and 70s' it was relatively cooler, and from the end of 70s' the temperature started to rise up, but was still below the peak value of the 40s'and 50s'.

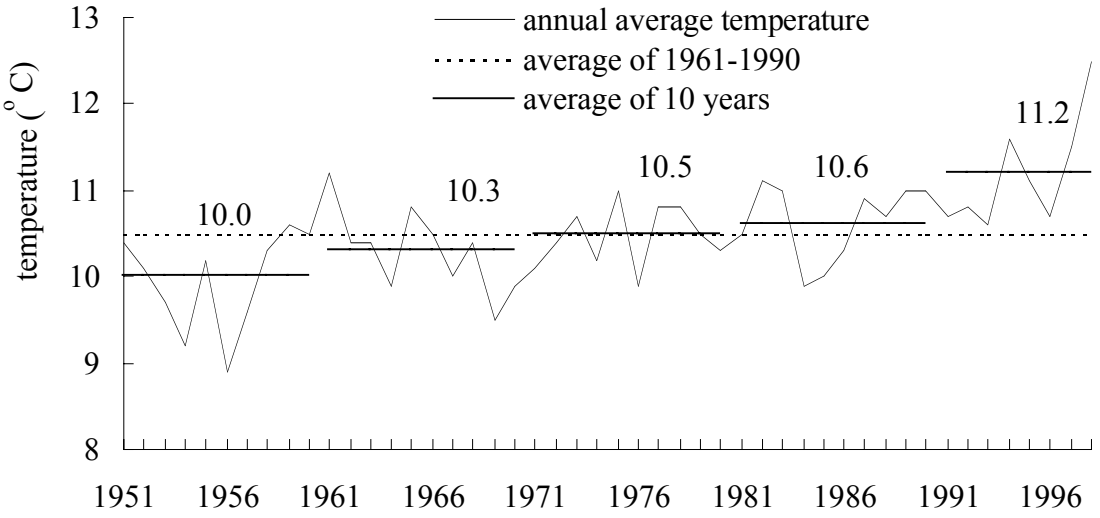


Figure 2. The curve of annual mean temperature of North China in recent 50 years

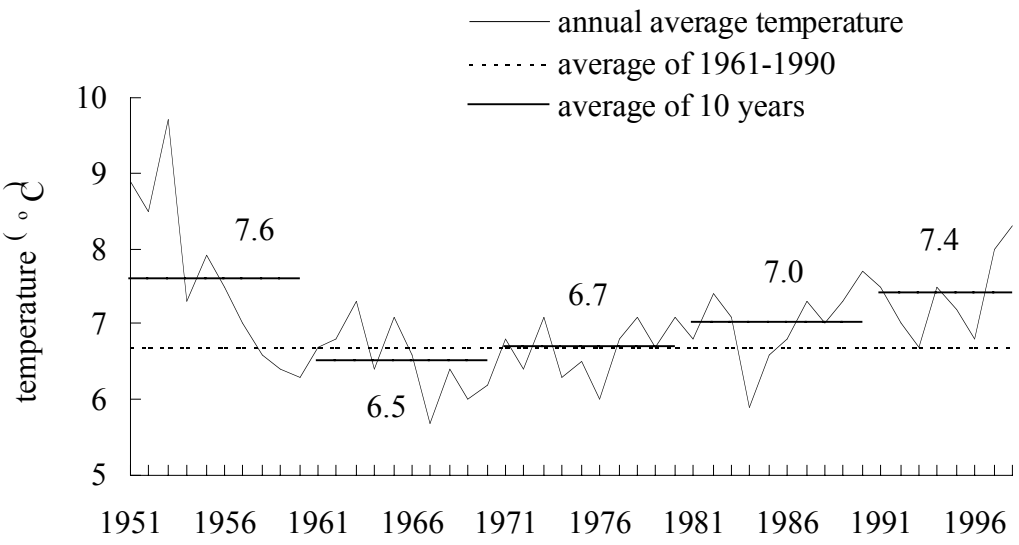


Figure 3. The curve of annual mean temperature of Northwest China in recent 50 years

On the centenary scale, the temperature change is characterized by a warmer climate in the early half of this century and a falling in temperature in the late half of this century, in northern areas this phenomenon is more striking than other parts of the country. The temperature rising in the recent 50years can be seen as the continual warming after the 30s' to 40s'. However, it is somewhat different from the steady global warming trend that a remarked drop in temperature occurred from the 50s' to 60s' in China. The rapid temperature rising in 90s' is universal as a result of the human activities.

Precipitation Change

Unlike the temperature change, the change of precipitation is rather obscure, and the locality is striking. On the whole, the precipitation of North China from the 1950s' to the 1990s' tended to decrease. In the 50s' and 60s', the precipitation was relatively abundant with an annual mean 20 *mm* more than average value, and in the 70s' the precipitation started to fall down, approaching the mean value. In the 80s', the precipitation decreased to the bottom, the mean is 40 *mm* less than that of the 50s', and in the 90s', there was a slight rising in rainfall from the 80s'(see figure 4).

The precipitation of Northwest China in the past 50 years changed as follows. Above normal in the 50s', with great fluctuating extent; and a slightly less than normal from the 60s' to the early 80s', with small changing extent; from the late 80s', the precipitation tended to rise up in a great changing extent (see figure 5). The east part or Northwest China differed from the west part in that the precipitation decreased in east part and increased in the west, divided by the Hexi Corridor.

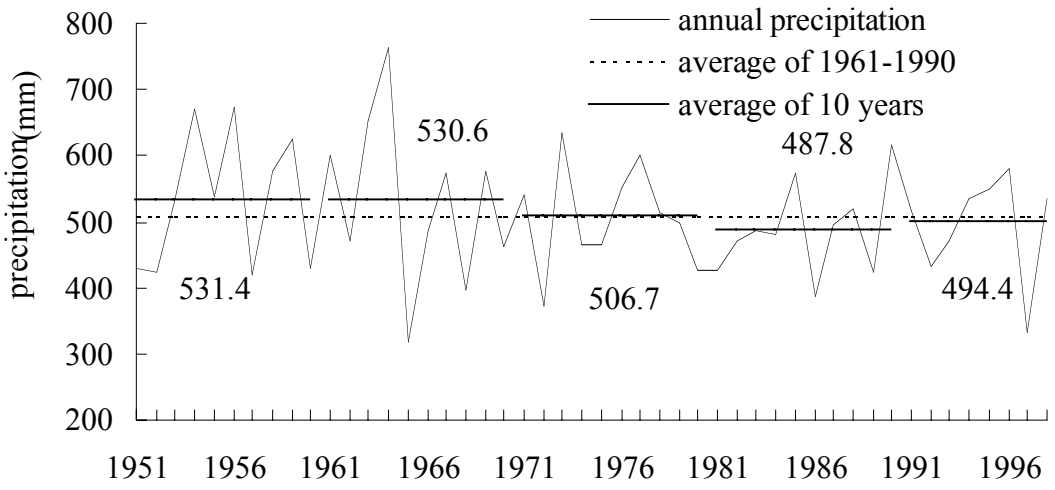


Figure 4. The curve of annual precipitation of North China in recent 50 years

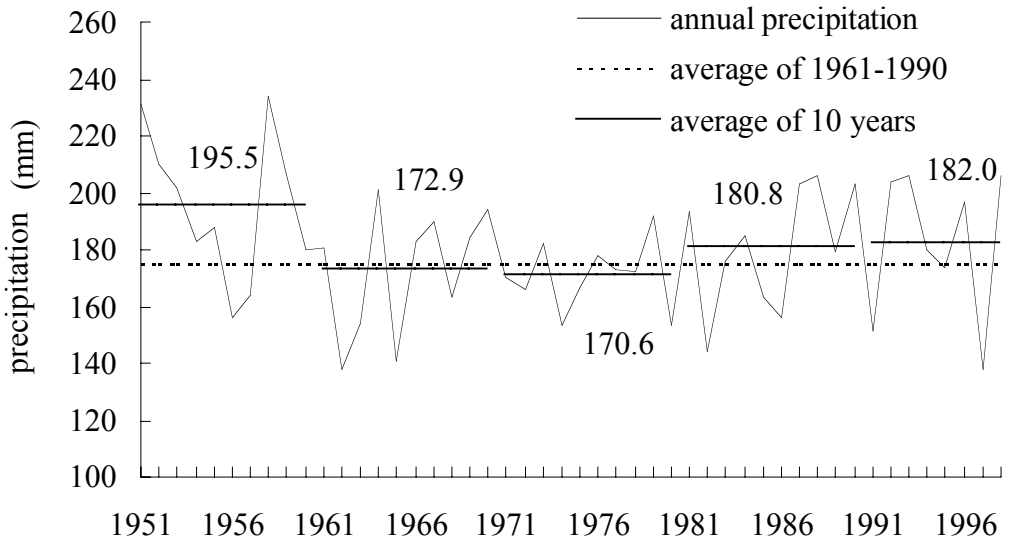


Figure 5. The curve of annual precipitation of Northwest China in recent 50 years

The precipitation in the high mountain area is the main water resources of Northwest China. Precipitation in this area is considerably rich and steady, the variation coefficient of precipitation is only 0.14 and that of the runoff is about the same grade. All the advantageous above guaranteed a rich and steady water source, which is favorable to water exploitation.

It should be mentioned that there had appeared many severe droughts in history in Northern China. On the basis of analysis of drought grade data of 520 years from 1470 to 1989, 8 most severe droughts had taken place in Gansu Province. One time in every 63 years in average and all occurred in the dry period in an alternate moist and dry period of 100 to 130 years. This alternating of moist period and dry period during 100 to 130 years is conformed with that of North China, and the according most

provinces of North China and Northwest China. For instance, serious droughts in 1634~1644, 1876~1878,and 1928~1929 had brought about millions and tens of millions people's death, which were far more than the 2400 thousand death in the world-shaking drought in Africa in the 80s'. In the recent 50 years, a few serious droughts had also appeared in our northern areas, the drought in 1972, for example, which had affected the Yangtze River and the Yellow River valleys and more than 10 provinces and cities of North China. Meanwhile 30.67 million hectares' farming lands were hit by this disaster. The middle and lower reaches of the Yellow River Valley and North China had a small precipitation the year before and suffered the spring drought again. As a result of this drought, the crops yield of nearly half provinces of all country suffered a loss, the reduction extent in Beijing, Tianjin, Hebei and Shanxi provinces were particularly high as they suffered most severe drought. In that year, water resources of most parts of the country were deficient or hemiplesia. Daily water supply dropped from 6 million tons to 700 thousand tons in Tianjin City.

It is even more critical that the continual 11years of drought had occurred twice, namely 1632~1642, 1922~1932 in the Yellow Valley in history. Severe droughts are the most serious disasters in northern China, the affecting period and range as well as the loss which cause is far beyond the other natural disasters. What's more, the corresponding unpeacement they cause affected the society significantly.

Experience in history shows that if there appears 2 continual year lack of rainfall in rain season, the soil moisture in deep layer will dramatically drop, and so most severs droughts may occur.

Impact of Climate Change on Water Resources

The impacts of climate change on water resources are displayed in every sector of water system. In this paper, we will pay attention to study on runoff, which are the most important and direct water resources.

According to trend analysis of real measured volume of flow in the main stations of the Yellow River and the Haihe River for recent 100 years and 40 years, the real measured volume of flow all had tended to fall down. The decreasing rate of 10 years is 36.64 percent for the Haihe River, 5.7 percent for the Yellow River. The volume of natural runoff also tended to go down, decreasing rate of 10 years is 22.5~23.4 percent for the Haihe River, 0.45 percent for the Yellow River. Taking into account the change of precipitation and temperature at the same period into account, it can be concluded that the climate might most probably changed warmer and drier in the Haihe River velly, secondary is in the Yellow River.

Nevertheless, difference between the changing trend of real measured volume of flow and natural volume of flow is largest in Haihe River, the next is the Yellow River. This indicates that resulting from the growing population and social economic development, water consumption has been increasing day by day and caused the reduction of flow volume in northern rivers. The Haihe River is the one mostly affected by climate change and human activities, and secondary is the Yellow River.

Figure 6 and 7 show the standardized anomaly of precipitation and volume of runoff of the Haihe and the Luanhe River valley, it shows a unanimous trend of runoff volume and precipitation.

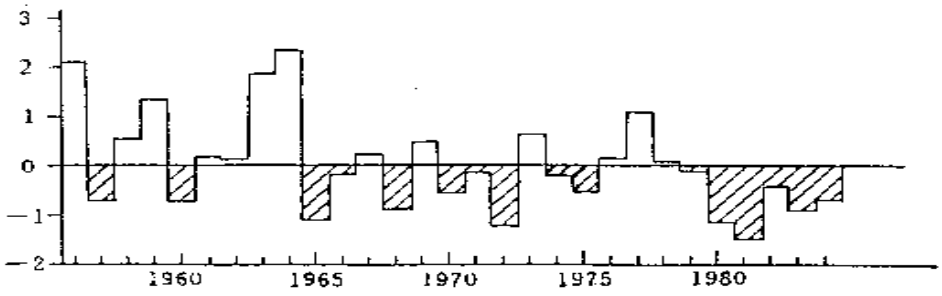
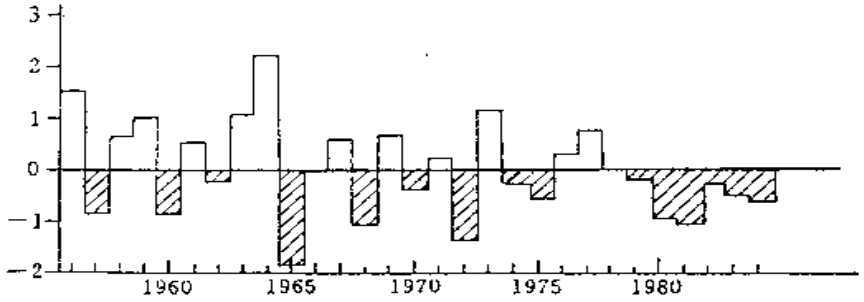


Figure 6. The curve of standardized anomaly of precipitation of Haihe River and Luanhe River

Figure 7. The curve of standardized anomaly of runoff of Haihe River and Luanhe River



In order to evaluate the gross water resources by precipitation, we set up models describing relationship between the water resources and the precipitation in four cities or provinces, namely Beijing, Tianjin, Hebei and Shanxi. The models could be written as the follows:

Beijing:	$y = 1.27\_10^{-2}\, x^{1.7224}$	r: 0.9798
Tianjin :	$y = 3.0068\_10^{-3} x^{1.9984}$	r: 0.9481
Hebei:	$y = 2.148\_10^{-4} x^{2.013}$	r: 0.9565
Shanxi:	$y = 9.64\_10^{-2} x^{1.0797}$	r: 0.8464

Where y is the estimated gross water resources ($10^8 m^3$), x is precipitation ($10^8 m$),

The runoff will be greatly influenced if a severe drought occurs. For instance, in 1997, affected by the El Nino event, the precipitation in northern China was abnormally small and temperature was abnormally high, which resulted in a great reduction of water resources in that year (see table 1). Volume of flow water of the Yellow River was small than that of the previous year, the natural volume of the Hua yuan kou was 20 billion less than normal year, and no-flowing was aggravated, the beginning time ,lasting period and the length all renewed the history record.

Table 1. The contrast of water resources of northern rivers of 1997 with normal_%_

Rivers	Precipitation	Volume of surface water	Volume of groundwater	Gross water volume
Songliao River	-11.4	-18.6	1.8*	-16.4*
Haihe River	-33.0	-54.5	-41.9*	-59.4*
Yellow River	-27.4	-42.5	-21.3	-36.7
Huaihe River	-19.5	-43.1	-26.9	-39.0
Inland rivers	-16.5	-4.7	-7.5	8.7

*compared with previous year

CLIMATE CHANGE IN THE FUTURE AND ITS IMPACT ON WATER RESOURCES

Temperature Change

By selecting 7 global climate models provided by the first science report and supplementary report of IPCC, Chinese scientists had calculated the possible impact on East Asia and China caused by the Greenhouse Effect and sulfide aerosol discharging (human activity) in the coming 50 years (see table 2 and 3). Figures in the tables show that around 2050, temperature of East Asia is likely to rise by 1.5_ because of human activity; temperature in northern China might be 1.3~1.4_ higher than now. Considering the natural climate change, temperature of northern China will rise 1.5~2.0_ by 2050,and the warming in winter will be more obvious, and extremely hot weather will occur more frequently.

Table 2. The possible impact of human activities on temperature of East Asia in the coming 50 years (__

Year	2000	2010	2020	2030	2050
Temperature change: highest value	0.30	0.50	0.80	1.20	1.85
Best value	0.20	0.35	0.65	0.88	1.40
Lowest value	0.10	0.25	0.50	0.60	1.00

Table 3. The possible impact of human activities on temperature of Northern China in the

coming 50 years (__

Year Area	2000	2010	2020	2030	2050
Northeast China	0.35	0.60	0.70	0.90	1.35
North China	0.25	0.50	0.65	0.85	1.30
Northwest China	0.30	0.60	0.70	0.90	1.30
Xinjiang Region	0.50	0.70	0.90	1.05	1.40

Precipitation Change

In addition, by using the same 7 models Chinese scientists had calculated the impacts of human activities on precipitation of East Asia and China, results are displayed in table 4 and 5. From these figures we can see that by 2050, precipitation in East Asia may increase 3~7 percent and probably 0.7~6 percent in northern China.

Table 4. The possible impact of human activities on precipitation of East Asia in the coming 50 years (%_
(compared with present climate)

Year	2000	2010	2020	2030	2050
Precipitation change_highest value	1.5	2.0	3.0	4.0	6.5
Best value	0.6	1.1.	1.9	2.6	4.2
Lowest value	0.3	0.7	1.2	2.0	3.0

Table 5. The possible impact of human activities on precipitation of Northern China in the coming 50 years (%)

Year Area	2000	2010	2020	2030	2050
Northeast China	1.0	2.0	2.5	3.0	4.0
North China	0.0	0.2	0.3	0.6	0.7
Northwest China	1.4	2.5	3.0	4.5	6.0
Xinjiang Region	1.8	3.0	3.5	4.5	6.0

The Impact of Climate Change in the Future on Water Supply and Demand

The above calculation indicated that warming caused by human activity by 2050 maybe more obvious, and although the precipitation in average is likely to increase

either, the increasing is rather small compared with that of temperature. The rising temperature will produce a rapider evaporation , as is calculated that the evaporation will increase 10~15 percent every 1_ temperature rising. Therefore, the adding in precipitation is not able to compensate the increased evaporation. This will lead to a reduction in water resources and added the more water demand, the tension of water demand and supply will be strengthened.

Furthermore, some studies show that the frequency and strength of extreme climate events, such as droughts, might increase in the future because of human activity changed the climate, which will evoke more menace to human society and economic developing, especially to the arid and semi-arid areas of northern China.

We should pay attentions that there's still some uncertainty in the study on relationship of human activity and climate change in the future, such as in discharging, land utilization and population growth etc. All these uncertainty might affect the correct assessment in some extent of water demand in the future.

ACKNOWLEDGEMENT

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REFERENCE

Xu Guochang et al, Climate Change in Arid and semi-Arid Region of China (in Chinese), 1997, Meteorological Press, Beijing.